Effect of Summon Preferred Food Source on Feeding, Tunneling, and Bait Station Discovery by the Formosan Subterranean Termite (Isoptera: Rhinotermitidae)

MARY L. CORNELIUS AND ALAN R. LAX

USDA–ARS, Southern Regional Research Center, 1100 Robert E. Lee Boulevard., New Orleans, LA 70124

J. Econ. Entomol. 98(2): 502–508 (2005)

ABSTRACT This study evaluated the effect of Summon Preferred Food Source on feeding, tunneling, and bait station discovery by the Formosan subterranean termite, *Coptotermes formosanus* Shiraki. Bioassays were conducted to determine whether Summon disks affected the aggregation and feeding behavior of termites and to determine whether the presence of Summon disks caused increased recruitment of termites to wood blocks. When termites encountered the disk, they immediately clustered on top of the disk. Termites were observed aggregating on top of the disk throughout the experiment. Consumption of Summon disks was significantly greater than consumption of cardboard disks in paired choice tests. The presence of a Summon disk on top of a wood block caused a significant increase in consumption of the wood block. Bioassays also were conducted to determine whether water extracts of Summon disks affected termite behavior. Consumption of filter paper disks treated with a water extract of Summon disks was significantly greater than consumption of control filter paper disks. Termites tunneled through sand treated with a water extract of Summon disks faster than they tunneled through untreated sand. In a field test, the rate of infestation of monitoring stations with a Summon disk was 3 times greater than the rate of infestations of stations without a disk.

KEY WORDS *Coptotermes formosanus*, aggregation, feeding stimulant, tunneling behavior, feeding behavior

SUCCESSFUL BAITING PROGRAMS have several advantages over the use of conventional termiticides as chemical barriers. First, baits are an environmentally sound alternative to conventional termiticides because baits only require a small amount of toxicant to be placed in a bait matrix (amounting to only a few grams of active ingredient per home) as opposed to the application of hundreds of gallons of termiticides underneath a structure. Second, the active ingredient in a termite bait station is targeted specifically at the molting process in an insect's life cycle, resulting in minimal mammalian toxicity. Third, there is no direct application of the active ingredient to the soil, minimizing the risks of problems due to runoff and groundwater contamination. Fourth, because termites consume the toxicant and pass it on to other colony members by trophallaxis, baits have the potential to eliminate a termite colony. Finally, the continual use of in-ground monitoring stations as part of a monitoring-baiting program enables pest management professionals to detect new termite activity in stations that may threaten the structure.

A major drawback of commercial baits is that termites need to discover the bait stations for the treatment to have any effect on the termite infestation in the structure. In some cases, it may take several months for termites to find bait stations, resulting in costly delays in eliminating the termite infestation. The use of attractants to increase the likelihood that termites will discover the stations could markedly improve the efficacy of commercial bait products.

Currently, commercial bait stations do not use attractants. However, there is considerable research interest in the development of attractants or substances that elicit trail-following behavior for use in baiting programs. Laboratory studies have been conducted with trail-following substances, such as 2-phenoxyethanol (Chen et al. 1998). Field experiments have been conducted using drenches of the soil surrounding the bait stations with solutions of sucrose + yeast or urea to attract termites to the stations (Waller et al. 1999). However, these drenches also could attract ants to bait stations and increase problems with ants infesting stations and excluding or preying upon termites.

Studies also have been conducted to identify stimulants/arrestants that can be used to improve the acceptability of the bait matrix. The following specific chemicals have been identified and patented as feed-

This article reports the results of research only. Trade and manufacturer names are given to describe experimental materials. Mention of a trademark or a proprietary product does not constitute a guarantee or warranty of the product by the USDA and does not imply its approval to the exclusion of other products that may also be suitable.

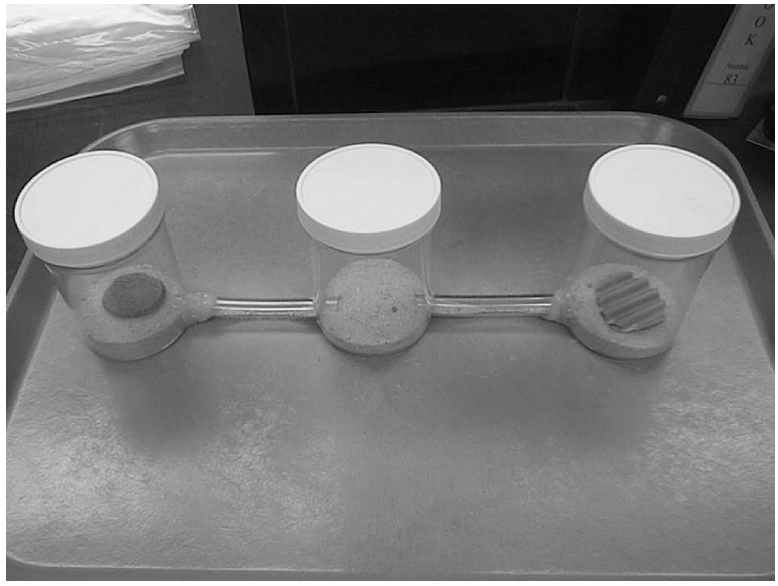

Fig. 1. Three-chambered testing apparatus for bioassays examining aggregation and recruitment of termites to wood blocks.

ing stimulants/arrestants for use in termite baits: cholesterol, dehydroisoandrosterone (Galinis and Strnad 2000), D-aspartic acid, L-glutamic acid (Chen and Henderson 1996), ergosterol (Henderson et al. 1999), and hydroquinone (Reinhard et al. 2002a, b). However, in tests comparing consumption by the Formosan subterranean termite, *Coptotermes formosanus* Shiraki, of filter paper disks treated with each of the specific chemicals mentioned above versus control disks over a range of concentrations, only ergosterol acted as a feeding stimulant (Cornelius 2003). Ergosterol has been incorporated into a cellulose-based bait matrix for termite control (Rojas and Morales-Ramos 2001).

This study examined the effect of the commercially available product, Summon Preferred Food Source (FMC, Philadelphia, PA), on the behavior of *C. formosanus.* This product is marketed as a preferred food source that can be used to decrease the time it takes for termites to find monitors or bait stations. Product information claims that "termites prefer Summon up to eight times more than any other food source. They begin feeding right away and 'summon' other termites from the colony by word of pheromone" (FMC Corporation 2004). Laboratory studies were conducted to evaluate the effects of Summon disks on the aggregation and feeding behavior of termites. Bioassays also were conducted to determine whether water extracts of Summon disks affected termite behavior. If water-soluble components of Summon disks influence termite feeding and tunneling behavior, the presence of Summon disks could potentially affect the rate of discovery of bait stations in the field. Finally, a field test was conducted to compare the rate of infestation of monitoring stations with or without a Summon disk present.

Materials and Methods

Termite Collections and Maintenance. Termites were collected from field colonies in New Orleans, LA, by using underground bucket traps (Su and Scheffrahn 1986) baited with blocks of spruce, *Picea* spp., wood. Termites were kept in the laboratory in 5.6-liter covered plastic boxes containing moist sand and blocks of spruce wood until they were used in experiments.

Bioassays Evaluating Aggregation Behavior on Summon. Bioassays were conducted to determine whether Summon (FMC, Philadelphia, PA) disks would elicit aggregation behavior by termites. Three clear polystyrene, cylindrical screwtop containers (9 cm in height by 7 cm in diameter) were connected using two 10-cm-length pieces of Tygon tubing (i.d. 3/4 in., o.d. 5/16 in., wall 1/32 in.) inserted through holes on the lower portion of the vertical wall of the containers and sealed in place with a glue gun. In each container, there was 50 g of sand (Frey Scientific, Mansfield, OH). In one container, a Summon disk was placed on top of the sand, and in another container a corrugated cardboard disk of the same diameter as the Summon disk was placed on top of the sand. There was only sand in the center container. In each container, 10 ml of distilled water was added to moisten disks and sand (Fig. 1). Groups of 200 termites (190 workers, 10 soldiers) were placed in the center container. Termites were able to move freely between the three containers. Each three-chambered testing apparatus was placed in an unlit incubator (28°C, 97% RH). For each experiment, termites from two different colonies were used, with five replicates from each colony. The number of termites in containers with the Summon disk or the cardboard disk were counted after 2 d and

compared using a *t*-test for matched pairs (termites located in center containers were not included in the analyses).

Bioassays Evaluating Feeding Behavior on Summon. A Summon disk and a cardboard disk were weighed and then placed on opposite sides of each other in a 9.0-cm-diameter glass petri dish containing 5 g of sand moistened with 2 ml of distilled water. The disks also were moistened with distilled water. Because a comparison of weight loss due to consumption of a Summon disk and a cardboard disk is a comparison of two dissimilar items, another bioassay was conducted where two cardboard disks were weighed and then placed on opposite sides of the petri dish. In this second test, the consumption of cardboard disks by termites in the absence of a Summon disk was determined. Average weight loss of cardboard disks due to consumption was then compared for tests using a Summon disk and tests without a Summon disk. This second test was conducted to obtain more information concerning the effect of the presence/absence of a Summon disk on the rate of consumption of cardboard by termites in this bioassay.

For each bioassay, termites from two colonies were used, with five replicates from each colony. For each replicate, 200 termite workers were placed in each dish and the dishes were placed in an unlit incubator (28°C, 97% RH) for 7 d. After 7 d, disks were removed from the dishes, and left to air dry for 24 h. Weight loss of each disk was determined. Consumption of Summon and cardboard disks was compared using a *t*-test for matched pairs, on a pooled data set from the two colonies. Also, average consumption of cardboard disks in the absence of a Summon disk was compared with the average consumption of cardboard disks in the presence of a Summon disk by using a *t*-test.

Bioassays Evaluating the Effect of Presence of Summon Disks on Consumption of Wood Blocks. Bioassays were conducted using three interconnected containers as described previously (Fig. 1), except that wood blocks were placed on top of the sand and disks were placed on top of the wood blocks. A block of spruce wood (4 by 3.5 by 1 cm) was oven-dried at 90°C for 24 h, weighed, and placed on top of the sand in two of the containers. Either a Summon disk or a cardboard disk was placed directly on top of each wood block. There was only sand in the center container. Groups of 200 termites (190 workers, 10 soldiers) were placed in the center container. For each experiment, termites from two different colonies were used, with five replicates from each colony. Each three-chambered testing apparatus was placed in an unlit incubator (28 C, 97% RH) for 6 wk. After 6 wk, wood blocks were oven-dried and weighed to determine termite consumption. Final weights of wood blocks were compared using a *t*-test for matched pairs.

Bioassays Evaluating Feeding Behavior on Filter Paper Disks Treated with Water Extract of Summon. The effects of a water extract from Summon disks on termite feeding behavior were evaluated using paired choice tests where termites were presented with a choice of a filter paper disk treated with either the water extract of the Summon disks or water alone. Bioassays were conducted to measure consumption after either 24 or 48 h. Two Summon disks were soaked in 100 ml of deionized water for 24 h. The water was then poured through a funnel lined with a Whatman no. 4 filter paper. The filtered water (a light brown) was used in bioassays. For each test, Whatman no. 1 filter paper disks (2.5 cm in diameter) were weighed and numbered. Numbers were written in pencil in the center of each disk. For each filter paper disk, 60 μl of either the extract or water alone was applied. One treated and one control filter paper disk were placed on opposite sides of each other in a 14.0-cm-diameter glass petri dish containing 20 g of sand moistened with 5 ml of distilled water. The number and treatment of each disk were written adjacent to each disk on the outer surface of the dish. In this way, the disk could be identified even if termites had consumed most of the disk. For each bioassay, termites from two colonies were used, with five replicates from each colony. For each replicate, 200 termite workers were placed in each dish, and the dishes were placed in an unlit incubator (29°C, 96% RH). After either 24 or 48 h, depending on the length of the bioassay, filter paper disks were removed from the dishes and left to air dry for 24 h. Weight loss of each disk was determined. Consumption of treated and control disks was compared using a *t*-test for matched pairs, on a pooled data set from the two colonies.

Bioassays Evaluating Tunneling Behavior in Sand Treated with Water Extract of Summon. The testing device was comprised of a 9-cm-high by 7-cm-diameter clear polystyrene cylindrical screwtop container (Consolidated Plastics, Twinsburg, OH) with a 5-cm length piece of Tygon tubing (0.8 cm i.d.) inserted through a hole on the lower side of the container and sealed in place with a hot glue gun. A plastic Y-tube (stem and arm lengths, 3 cm; diameter, 1 cm) was attached to the distal ends of the Tygon tube and another 5-cm length piece of Tygon tubing (0.8-cm i.d.) was attached to each arm of the Y-tube. A 1-ml disposable pipette tip (length, 7 cm; diameter, 1 cm at wide end) was attached to the other end of the Tygon tubing (Fig. 2). A thin layer of moist sand (Frey Scientific) was placed on the bottom of the container. Termites were able to move freely from the container into the tubing. In each container, 200 *C. formosanus* workers were placed in the center of the container. Termites from two colonies were used, with 15 replicates from each colony. Summon disks were extracted in water as described previously. For each replicate, one arm of the Y-tube was connected to a pipette tip filled with sand treated with a water extract of Summon and the other arm of the Y-tube was connected to a pipette tip filled with sand treated with deionized water. There was no sand in the Y-tube itself. Therefore, termites would initiate tunneling in the sand in one or both of the pipette tips. The position of the treatment and control tips on the arms of the Y-tube was rotated between replicates to preclude any positional effects. Each pipette tip was marked on the outer surface with a permanent marker at a distance

Fig. 2. Testing device for bioassays examining tunneling behavior of termites.

of 2 cm from the narrow end of the pipette tip (Fig. 2.). Tunneling activity was continuously observed until termites reached this mark. As soon as termites reached this mark in one of the tips attached to each Y-tube, both tips were removed and the number of termites in each tip was counted. These tests were conducted in ambient conditions in the laboratory.

Field Test Comparing the Rate of Infestation of Monitoring Stations with or without Summon Disks. A field test was conducted in City Park in New Orleans, LA, at locations where termite populations have been monitored for two or more years by using underground bucket traps. Testing sites within these locations of City Park were selected by choosing 14 trees that were infested with *C. formosanus* and had an active bucket trap located at the base of the trunk. The 14 trees were located in three different sections of City Park and were infested by at least seven different termite colonies. The foraging ranges of colonies in each section had been at least partially delineated using mark–release–recapture techniques. There were 84 HomeChoice Termite Detector Stations (Dallas Ft. Worth Pest Control, Dallas, TX). The only modification made to these stations was that the hole in the bottom of each station was enlarged from ≈0.5 to 1 cm in diameter. The stations were installed in the field along with the balsa type wood block that was included with the stations. In 42 of these stations, a Summon disk was placed in the bottom of the station underneath the wood block. The other 42 stations contained only the wood. Six monitoring stations, three with a Summon disk and three without a Summon disk, were arranged in a semicircle around each tree, ≈1 m from the tree trunk. In each semicircle, the positions of stations with or without a Summon disk were alternated and each station was placed 1 m apart from each other and at least 1 m from the active bucket trap. The monitoring stations were placed in the field on 6 May 2004 and checked for termite activity on the following dates: 27 May, 15 June, 28 June, 12 July, and 26 July 2004. Termite activity included stations where termites were present and stations where visible signs of a termite presence were evident (feeding damage on wood blocks, mud tubes inside of the station). Therefore, the number of monitoring stations discovered by termites included any stations that had been infested and abandoned by termites, unless termites abandoned stations without leaving any visible evidence of their presence (feeding damage on wood blocks, mud tubes inside of the station). The number of stations with and without a Summon disk that were discovered by termites over a 12-wk period was compared using a one-way analysis of variance (ANOVA).

Results and Discussion

Bioassays Evaluating Aggregation Behavior on Summon. There were significantly more termites in the containers with the Summon disk than in the containers with the cardboard disk (Fig. 3.). When termites encountered the Summon disk, they immediately clustered on top of the disk. Termites were observed aggregating on top of the disk throughout the experiment, and they had begun to construct tunnels into the disk by the end of the bioassay.

Bioassays Evaluating Feeding Behavior on Summon. Consumption of Summon disks was much greater than consumption of cardboard disks in paired choice tests after 7 d (Table 1). Because the Summon and cardboard disks are such different materials, it was hard to interpret differences in the consumption of the two disks. Therefore, another experiment was performed where two cardboard disks were paired with each other. Average consumption of each cardboard

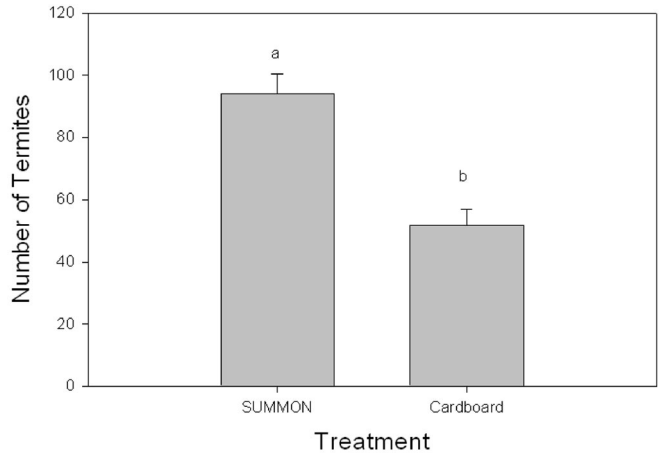

Fig. 3. Mean (±SEM) number of termites in sand-filled containers with either a Summon or a cardboard disk placed on top of the sand.

disk in tests where termites had a choice of two cardboard disks was then compared with average consumption of cardboard disks in tests where termites had a choice of a cardboard disk or a Summon disk. When termites were given a choice of two cardboard disks, the average consumption of each cardboard disk was greater than in tests where a cardboard disk was paired with a Summon disk ($P = 0.002$) (Table 1). The results of these two experiments demonstrate that consumption of the Summon disk was greater than consumption of the cardboard disk.

Bioassays Evaluating the Effect of the Presence of Summon Disks on Consumption of Wood Blocks. Consumption on wood blocks with a Summon disk placed on top was significantly greater than on wood blocks with a cardboard disk placed on top (Table 1). Because termites aggregated on the Summon disk and tunneled through the disk into the wood block, the aggregation effect of the disk resulted in increased consumption of the wood block. These results indicate that aggregation on a Summon disk within a bait station could result in recruitment to the wood in the station.

Table 1. Feeding preferences of termites in paired choice tests

Experiment	Wt loss of disks/ blocks(mg)
Experiment 1: Summon vs. cardboard	
Summon	205.0 ± 28.0a
Cardboard	30.0 ± 3.0b
Experiment 2: Cardboard vs. cardboard	
Cardboard (1)	51.0 ± 7.0a
Cardboard (2)	55.0 ± 5.0a
Experiment 3: Summon on top of wood block vs. cardboard on top of wood block	
Wood block with Summon	377.0 ± 41.0a
Wood block with cardboard	139.0 ± 35.0b
Experiment 4: 24-h feeding test, water extract of Summon	
Filter paper with Summon	8.0 ± 1.0a
Untreated filter paper	3.0 ± 1.0b
Experiment 5: 48-h feeding test, water extract of Summon	
Filter paper with Summon	32.0 ± 1.0a
Untreated filter paper	10.0 ± 2.0b

Within an experiment, letters that are different indicate significant differences ($P < 0.05$; *t*-test).

Bioassays Evaluating Feeding Behavior on Filter Paper Disks Treated with Water Extract of Summon. After both 24 and 48 h of feeding, consumption of filter paper disks treated with a water extract of Summon disks was greater than consumption of untreated filter paper disks (Table 1). These results show that water soluble components of the Summon disks affect termite feeding behavior and could potentially leach into the soil surrounding a bait station.

Bioassays Evaluating Tunneling Behavior in Sand Treated with Water Extract of Summon. In paired choice tests, termites tunneled through sand treated with an extract of Summon disks first in 23 of 30 replicates ($P = 0.006$; sign test). The average number (±SEM) of termites in pipette tips filled with extract-treated sand (31.7 ± 1.2) was significantly greater than the average number of termites in tips filled with untreated sand (25.2 ± 1.6) ($P = 0.001$; a *t*-test for matched pairs). The increase in the rate of tunneling by termites in response to the presence of water-soluble components of Summon disks could result in an increase in the construction of tunnels near bait stations containing Summon disks. If water-soluble components of Summon disks that leached into the soil could direct termite tunneling toward bait stations, the Summon disks could potentially increase the likelihood that bait stations are discovered by termites.

Field Test Comparing Rate of Discovery of Monitoring Stations with and without Summon Disks. When monitoring stations were first inspected on 27 May 2004, there were eight stations infested by termites, four stations with a Summon disk and four control stations. The number of stations containing a Summon disk that were infested by termites gradually increased over time, whereas only a single new control station was infested by termites after the first inspec-

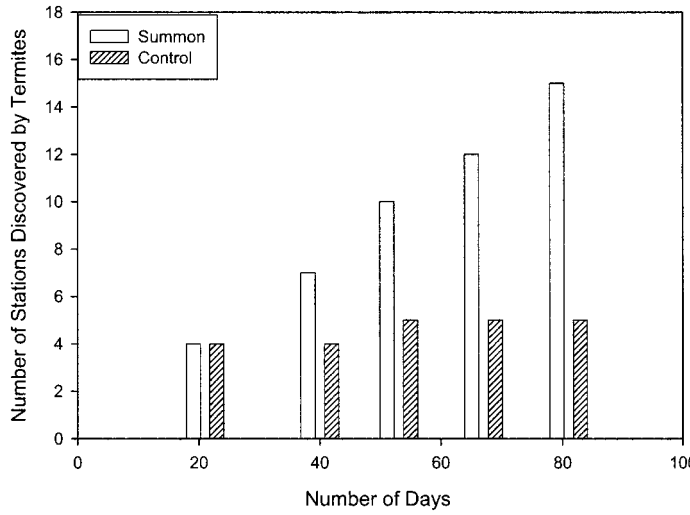

Fig. 4. Total number of monitoring stations with or without a Summon disk discovered by termites on each inspection date over a 12-wk period.

tion (Fig. 4). After 12 wk, there were 15 stations with a Summon disk (36%) that had been discovered by termites compared with only five control stations (12%). There was no evidence that termites were finding and abandoning either treated or control stations before causing heavy damage to the wood block. The difference in the number of stations with and without a Summon disk that were discovered by termites over a 12-wk period is significant ($F = 6.9$; df = 1, 82; $P = 0.01$; one-way ANOVA).

The pattern of infestation of control stations illustrates the problem with conventional commercial bait stations. Stations infested by termites within the first 3 wk most likely represent stations that were placed in positions that intersected the existing termite gallery system. Although stations were placed in locations where termite activity was high based on monthly inspections of bucket traps, only one additional control station was infested by termites after the initial inspection. Formosan subterranean termites do not detect the presence of sound wood when tunneling through the substrate even at distances as short as 2.5 mm (Cornelius and Osbrink 2001, Puche and Su 2001). Therefore, bait stations are often not discovered by foraging termites, even in areas of high termite pressure.

The steady increase over time in the number of stations containing a Summon disk that were infested by termites indicates that the presence of the disks directed termite foraging toward the monitoring stations. It should be noted that during the 12-wk period of this field test, it rained frequently. The heavy rainfall most likely contributed to the high rate of discovery of stations with a Summon disk by causing water-soluble components of the disks to leach into the soil surrounding the station.

In conclusion, the Summon disks clearly affected termite behavior. The disks acted as feeding stimulants, caused continual aggregation behavior on disks throughout the bioassays and resulted in recruitment of termites to wood. Therefore, the presence of a Summon disk within a monitoring station would increase the acceptability of wood or bait matrix in that station. However, termites generally infest bait stations once they find them. The increased feeding of filter paper disks treated with a water extract of Summon disks and the increase in the rate of tunneling in sand treated with a water extract of Summon disks demonstrates that water-soluble components of a Summon disk influence termite foraging behavior. The field test determined that the presence of the disks dramatically increased the rate of infestation by termites. This increase in the rate of infestation in the field suggests that water-soluble components of the disks leach into the soil surrounding the station and cause termites to direct their foraging behavior toward the station. Hence, Summon disks have the potential to improve the efficacy of commercial baits by increasing the rate of discovery of stations in the field.

Acknowledgments

We thank Leanne Duplessis for invaluable technical assistance in conducting the bioassays. We also thank Weste Osbrink, Gregg Henderson, and Lisa Lyn for constructive comments on earlier versions of this manuscript.

References Cited

Chen, J., and G. Henderson. 1996. Determination of feeding preference of Formosan subterranean termite (*Coptotermes formosanus* Shiraki) for some amino acid additives. J. Chem. Ecol. 22: 2359–2369.

Chen, J., G. Henderson, and R. A. Laine. 1998. Isolation and identification of a 2-phenoxyethanol from a ballpoint pen ink as a trail-following substance of *Coptotermes formosanus* Shiraki and *Reticulitermes* sp. J. Entomol. Sci. 33: 97–105.

Cornelius, M. L. 2003. Evaluation of semiochemicals as feeding stimulants for the Formosan subterranean termite (Isoptera: Rhinotermitdae). Sociobiology 41: 583–591.

Cornelius, M. L., and Osbrink, W.L.A. 2001. Tunneling behavior, foraging tenacity, and wood consumption rates of Formosan and eastern subterranean termites (Isoptera: Rhinotermitidae) in laboratory bioassays. Sociobiology 37: 79–94.

FMC Corporation. 2004. Summon preferred food source: information for the PMP. (http://pestsolutions.fmc.com/Pest_Solutions/Product/0,1673,1914,00.html).

Galinis, D. L., and S. P. Strnad. 2000. Methods and compositions for attracting and controlling termites. United States Patent US6093389.

Henderson, G., J. Chen, and R. A. Laine. 1999. Compositions and methods for detecting and killing termites. United States Patent US5874097.

Puche, H., and N.-Y. Su. 2001. Tunnel formation by *Reticulitermes flavipes* and *Coptotermes formosanus* (Isoptera: Rhinotermitidae) in response to wood in sand. J. Econ. Entomol. 94: 1398–1404.

Reinhard, J., M. J. Lacey, F. Ibarra, F. C. Schroeder, M. Kaib, and M. Lenz. 2002a. Hydroquinone: a general phagostimulating pheromone in termites. J. Chem. Ecol. 28: 1–14.

Reinhard, J., M. L. Lacey, and M. Lenz. 2002b. Application of the natural phagostimulant hydroquinone in bait systems for termite management (Isoptera). Sociobiology 39: 213–229.

Rojas, M. G., and J. A. Morales-Ramos. 2001. Bait matrix for delivery of chitin synthesis inhibitors to the Formosan subterranean termite (Isoptera: Rhinotermitidae). J. Econ. Entomol. 94: 506–510.

Su, N.-Y., and R. H. Scheffrahn. 1986. A method to access, trap, and monitor field populations of the Formosan subterranean termite (Isoptera: Rhinotermitidae) in the urban environment. Sociobiology 12: 299–304.

Waller, D. A., S. E. Morlino, and N. Matkins. 1999. Factors affecting termite recruitment to baits in laboratory and field studies, pp. 597–600. *In* W. H. Robinson, F. Rettich, and G. Rambo [eds.], Proceedings of the Third International Conference on Urban Pests, 19–22 July 1999. Czech University of Agriculture, Prague, Czech Republic.

Received 7 October 2004; accepted 22 December 2004.